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A SEP Mission to Jupiter Using the Stretched Lens Array

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Abstract

As space exploration continues to be a primary focus of NASA, solar electric propulsion (SEP) becomes a forerunner in the mode of transportation to reach other planets in our solar system. Several critical issues emerge as potential barriers to this approach such as reducing solar array radiation damage, operating the array at high voltage (>300 V) for extended times for Hall or ion thrusters, and designing an array that will be resistant to micrometeoroid impacts and the differing environmental conditions as the vehicle travels further into space. It is also of great importance to produce an array that is light weight to preserve payload mass fraction and to do this at a cost that is lower than today's arrays. This paper will describe progress on an array that meets all these requirements and will detail its use in a solar electric mission to Jupiter.

From 1998-2001, NASA flew the Deep Space 1 mission that validated the use of ion propulsion for extended space missions. This highly successful two-year mission also used a novel SCARLET solar array that concentrated sunlight eight-fold onto small area solar cells. This array performed flawlessly and within 2% of its projected performance over the entire mission. That design has evolved into the Stretched Lens Array (SLA) shown in figure 1. The primary difference between SCARLET and the SLA is that no additional glass cover is used over the silicone lens. This has led to significant mass, cost and complexity reductions. The module shown in figure 1 is the latest version of the design. This design leads to a specific power exceeding 300 W/kg at voltages exceeding 300 V. In addition, this module has been tested to voltages over 1000 V while under hypervelocity particle impact in a plasma environment with no arcing. Furthermore array segments are under test for corona breakdown that can become a critical issue for long term, high voltage missions.

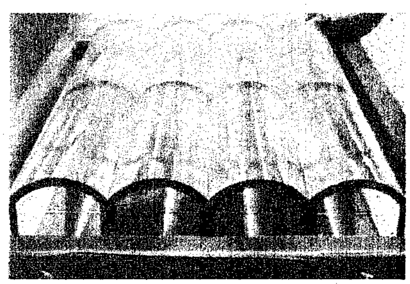

Figure 1: Lightweight SLA module

SEP missions to Jupiter, with its exceptional radiation belts, would mandate a radiation-resistant solar array to compete with a radioisotope alternative. Because of the concentrator design, the ~10 cm^2 cells, designed for 8x concentration can be shielded against radiation damage at about $1/8^{th}$ the mass of a conventional planar array. Comparisons of the mass differences in this design compared to planar arrays will be presented for a Jupiter mission. Because the glass covering the lens in the SLA design has been eliminated, much attention has been devoted to showing that the lens is durable to the space environment. Combined electron and proton testing has been conducted that confirms the durability to those hazards. UV and VUV testing of lens segments coated with resistant materials show no damage over more that 1000 hrs of testing. In addition, space tests on MISSE 1 on uncoated lenses and lenses coated with early coating compositions show excellent performance. Samples of the current lenses will be flown on MISSE 6. Additional durability results will be presented in the paper.

This paper will describe a spiral out trajectory to Jupiter including a radiation analysis of the SLA through the Van Allen Belts and Jupiter's radiation belts. Calculations of solar cell efficiency loss due to radiation using the SAVANT radiation damage code will be presented, and the results will be used to optimize solar cell coverglass thickness. Terrestrial and space testing of the SLA will be documented showing its applicability to a SEP mission. Current data from a direct drive experiment of 600 V being performed at Auburn University will also be presented. The goal of this demonstration is to prove reliable operation of a Hall thruster from a high voltage concentrator array. Testing will include the addition of Stretched Lens Array (SLA) hardware in the chamber at Auburn to measure plume impingement effects at various positions relative to the exhaust axis of the thruster. The SLA is durable, reliable, radiation resistant, lightweight, and cost-effective. The Stretched Lens Array is an optimal candidate for deep space electric propulsion missions to Jupiter and beyond.